



Document #: JPA-K1-SCR-DR-001

October 27th, 2010

Pamela Mazakas
U.S. Environmental Protection Agency
MC 2242A
1200 Pennsylvania Ave.
Washington, D.C. 20460

Object: Lafarge – U.S. EPA Consent Decree

Dear Mrs. Mazakas,

Pursuant to section XI (review and approval of submittals) of the Lafarge – U.S. EPA Consent Decree and pursuant to paragraph 4 of the Consent Decree Appendix, please find herewith the Design Report for our Joppa, Illinois facility pertaining to the installation of a Selective Catalytic Reduction (SCR) control technology on Kiln 1.


Respectfully submitted,

A handwritten signature in blue ink, appearing to read 'JF Latimier', with a long horizontal flourish extending to the right.

Jean-Francois Latimier
Compliance Director, EPA projects

CC: per transmittal form attached

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Transmittal form number: JPA-K1-SCR-DR-002		Issued by: J-F Latimier		Date: Oct 27, 2010	Page 1 of 1
LAFARGE – U.S. EPA CONSENT DECREE				Affected Plant:	Joppa, IL
Issued to: U.S. EPA MC 2242A 1200 Pennsylvania Ave. NW Washington, D.C. 20460				Attention: Pamela Mazakas	
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DOCUMENTS

DOCUMENT NO.	DOCUMENT NAME	DOCUMENT DESCRIPTION
JPA-K1-SCR-DR-001	JPA K1 SCR Design Report – Rev 0	Design Report for Joppa Kiln 1 SCR – Revision 0

	Design Report Selective Catalytic Reduction	Plant: Joppa	
		Revision:	0


Lafarge – U.S. EPA Consent Decree Design Report

Plant: Joppa
 Affected State: Illinois
 Affected Kiln: K1
 Pollutant: Nitrogen oxide (NO_x)
 Control Technology: Selective Catalytic Reduction

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1. Introduction

Pursuant to the terms of the Consent Decree between the Lafarge Companies, the United States and certain Affected States, several of Lafarge's U.S. cement plants are required to implement various control technologies on certain kilns in order to reduce sulfur dioxide (SO₂) and/or nitrogen oxide (NO_x) emissions.

A requirement of the Consent Decree is the submittal of a control technology design report for each affected Kiln for each control technology. This document is the design report covering the NO_x control technology requirement prescribed for the Joppa kiln no. 1 (K1) under Section V. A., Paragraph 34 of the Consent Decree. The specified technology for this kiln is selective catalytic reduction (SCR).

The following is an excerpt from the Consent Decree Appendix (Section II. d.) describing the basic requirements of the design report for SCR.

Selective Catalytic Reduction (SCR): The Lafarge Companies shall depend on vendor recommendations for design of an SCR to be installed on the Joppa Kiln #1 (or an alternate Kiln pursuant to Paragraph 37 of the Consent Decree). The Lafarge Companies shall request proposals from vendors for design of an SCR at Joppa Kiln 1 that is capable of reducing emissions of NO_x by up to 80 %. The Lafarge Companies shall submit to U.S. EPA and the Affected State a final Design Report that justifies and identifies the amount and type of reagent and catalyst to be used, the manner of reagent injection and all other relevant design parameters selected for the equipment, including vendor recommendations for design and operation of the SCR.

The SCR system will be optimized consistent with the requirements of the Consent Decree Appendix. Once the control technology operation is optimized, a 30-day rolling average emission rate will be determined after a 12-month demonstration period. The SCR technology must be installed before 31 July 2013 and must be used after that whenever the kiln is operating.

This design report outlines the basic scope of the project as per the CD Appendix.

2. Control Technology – Selective Catalytic Reduction (SCR)


SCR is a NO_x control technology involving the injection of an ammonia-based reagent – typically anhydrous or aqueous ammonia (NH₃ or NH₄OH, respectively) – into a gas stream and then passing the gas stream through a catalyst bed which promotes the reactions that convert NO_x into nitrogen (N₂) and water vapor (H₂O).

Primary Reactions

The main chemical reactions that occur are as follows:



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Secondary Reactions

There are also several side reactions that take place which impact the operation and life cycle of the SCR reactor and associated equipment.



The stoichiometric ratio between NH_4OH and NO/NO_2 is 1.0:1.

Side reactions (3) and (4) cause slightly higher ammonia consumption.


The reaction to form SO_3 (5) cannot be totally avoided.

Further reactions as in equations (6) and (7) depend on SO_3 and NH_4OH content in the flue gas and on temperature.

The effective operating gas temperature range for SCR applications is approximately 550-800 °F. If the temperature is too low, NO_x reduction may not be as efficient, and ammonium sulfate and ammonium bisulfate may form (resulting in build-up and plugging of the catalysts). If the temperature is too high, there is a risk of damaging the catalysts (sintering occurs), and the potential for ammonia to convert to NO_x .

The reagent is typically injected upstream of the SCR unit so as to achieve thorough mixing with the flue gas and uniform gas distribution through the reactor.

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3. SCR Reagent Options

There are three primary reagents used with SCR: anhydrous ammonia, aqueous ammonia, or urea solution.

Anhydrous Ammonia

Anhydrous ammonia (NH_3) is an effective SCR reagent but there are several permitting and safety issues (it is classified as a hazardous material) involved with the handling of anhydrous ammonia^[1] which make it unattractive for use as an SCR reagent.

Aqueous Ammonia

Aqueous ammonia (NH_4OH) is also an effective SCR reagent. It is typically available in concentrations of 19 and 25 % (mass basis), but can be specified for any concentration up to 29.4 %.

Solutions above 20 % ammonia are classified as toxic substances under CAA 112(r)(1), 40 CFR Part 68 (Chemical Accident Prevention Provisions), and 6 CFR Part 27 (Chemical Facility Anti-Terrorism Standards). The primary drawback of using concentrations above 20 % is a storage limit of 20,000 lb. Hence, the 19 % solution is generally selected even though it has higher freight and storage costs than anhydrous ammonia due to the increased quantity resulting from the water content.

Urea Solution


Urea [$\text{CO}(\text{NH}_2)_2$] solution can also be used as an SCR reagent. It is typically available in concentrations of 40 and 50 % (mass basis), but can also be found in concentrations of 32.5, 60 and 70 %.

Urea is not classified as a hazardous substance. This makes transportation and storage simpler than for ammonia. One stipulation is that the urea solution must remain above room temperature (~ 77 °F) or the urea may precipitate from the solution. Additionally, trials have shown that urea will vaporize when placed in contact with hot materials (decomposition occurs at 271 °F).

The proposed SCR system will be designed to handle 19 % aqueous ammonia.

¹ CAA (Section 112(r)(1) and 40 CFR 68); EPCRA (40 CFR 355 and 370); CERCLA (40 CFR 302); DOT (49 CFR 100-180); OSHA (29 CFR 1910.111, 29 CFR 1910.111, and 29 CFR 1920.120).

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4. Plant-Specific Factors Affecting Design

The SCR system will be operated as a clean gas system, downstream of the existing ESP on K1 in the temperature range of 570-660 °F. The ESP is presently in compliance with the PM emission limit at the current operating temperature of around 390 °F. It is planned to incorporate a gas cooling system and a fabric filter downstream of the SCR reactor in order to comply with PM emission standards under the future operating conditions.

The design of the SCR system is based on the following design considerations:

- Selection of catalyst type and pitch to match NO_x reduction requirements to cement process conditions
- Equipment design parameters selected to maximize surface contact between flue gas and catalyst to promote NO_x reduction reactions while providing an economical reactor design
- Good mixing of ammonia with flue gas to assure efficient reagent reaction and high NO_x emissions reduction

The catalyst is to be of the honeycomb design with a pitch that will vary depending on the vendor selected. Blowers with heated air are required to clean the dust from the catalyst layers.

Aqueous ammonia will be injected via dual-fluid nozzles by means of compressed air into the flue gas either upstream of the SCR reactor or upstream of the ESP.

Based on the recommendations of all vendors, an SCR bypass will be required for operational flexibility and isolation of the SCR unit when necessary.

5. Project Scope of Work

The project scope of work is for installation of an SCR system that includes reagent storage, a metering system, a reagent distribution system, and the SCR unit, downstream of the existing electrostatic precipitator. A gas cooling system, an induced draft fan, and a polishing fabric filter will also be needed. See Appendix 1 for a rudimentary flow sheet.


The SCR system will be designed to support use of 19 % aqueous ammonia as the reagent. The nominal reagent (19 % aqueous ammonia) rate is expected to be in the range of 2.3-3.4 gpm in the case of Joppa K1.

The reagent storage system will include all necessary instrumentation to ensure a safe operation. Instrumentation will include a level transmitter, a high level switch, and appropriate relief devices. A vapor recovery system will be utilized to ensure that vapor release is minimized during truck unloading.

Flow will be controlled via a flow meter and flow control valve, or via a metering pump. Nozzles will be atomizing type nozzles to ensure that the correct reagent droplet size is achieved. Compressed air will be used for atomization.

Even though an ammonia nozzle grid is commonly used in power industry applications, the relatively low reagent injection rate will only require one or two nozzles with diverting plates (mixers) and vanes (swirl breakers) for thorough mixing and even distribution of the reagent prior to entering the SCR reactor.

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6. Vendor Standards/Options

Meetings were held with several vendors including GEA Bischoff, Alstom, Elex CemCat, and Babcock & Wilcox to discuss the design of the SCR system. All of the vendors have installed numerous SCR units but have limited, if any, experience in cement industry applications. Proposals were received from the vendors for design of the Joppa K1 SCR system that is capable of reducing the emissions of NO_x by up to 80 %.

Appendix 2 is a table summarizing the vendors' experience and design considerations. The right-hand column provides the selected design parameters for the design report based on the vendors' recommendations. In summary,

- Honeycomb catalyst with 2-3 active layers for NO_x reduction
- Catalyst to be constructed with TiO₂ substrate and V₂O₅ as the active ingredient
- Catalyst pitch of 6-8 mm, depending on vendor selected
- Catalyst modules ~ 1.0-1.5 m in height
- Pressure drop estimated to be ~ 3.5-4.5 in WG
- Aqueous ammonia as reagent
- 1-2 injection nozzles with mechanical mixer
- Dust cleaning is by heated compressed air via nozzles
- SCR bypass during start-up to reach minimum operating temperature and during ESP failure


7. Conclusions and Recommendations

Selected reagent is 19 % aqueous ammonia.

Reagent rate (aqueous ammonia) is expected to be in the range of 2.3-3.4 gpm.

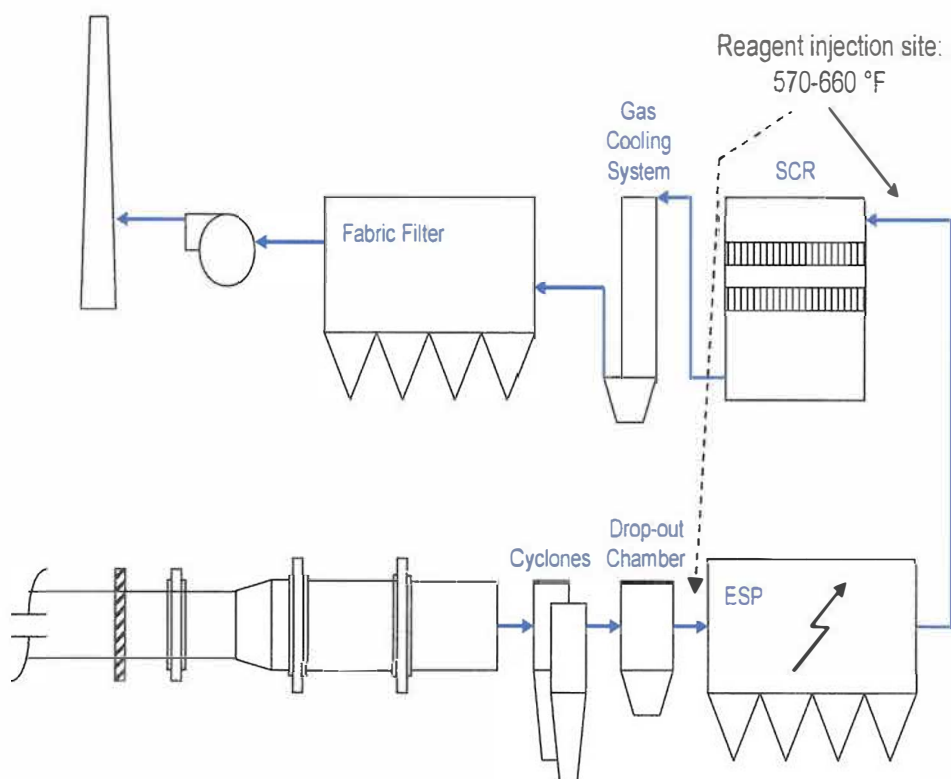
Location of injection will be either between ESP and SCR reactor or before the ESP in temperature zone of 570-660 °F.

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Appendix 1 – Joppa K1 SCR System

SCR – Joppa K1



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Appendix 2 – SCR Vendor Comparison

JOPPA KILN 1 SCR - VENDORS RECOMMENDATIONS					
DATE: Oct 25, 2010	GEA - Bischoff	Power Alstom	Cemcat (Elex/Polysius)	Babcock & Wicox	Recommendations for design considerations
COMPANY PROFILE					
Employees worldwide	20,000 in GEA Group; headquartered in Essen. 4,500 in GEA Process Engineering Segment	96,500 in Group; 1400 in Environmental Control Systems; R&D in Sweden	60-40 JV of Polysius and Elex; 80 in Zurich competence center for process design, basic engineering and layout	15,000 in power generation, nuclear operations, nuclear energy, and technical services group	
Employees US	2,000; GEA-Bischoff is part of GEA Process Engineering Division in Columbia, Maryland.	300 in Knoxville, TN including SCR core competence	Polysius for supply, contract execution	9,300 in Ohio with Power generation group; 2,000 in Utility, Industrial, Environmental, and Services division in Barberton, OH	Reliable service support from vendor is important
Multi-pollutants	NOx, SO2, D/F	NOx, SO2, D/F	NOx, THC, D/F	FGD, SCR, Hg	Multi-pollutants
Contracting capability	"Turnkey" up to \$15M	EPC	Turnkey	EPC	OEM
SCR REFERENCES					
SCR in Industry types	Glass, chemical, iron & steel, cement	35 GW installed in power industry; 90 SCR installed	Waste incineration, glass and cement	27 GW installed in power industry	
SCR in cement plants	2010 - Rohrdorf, scheduled to start in Sep 2010; high PHT gas temp	none	2001 - Solnhofen 2006 - Monselice; 2010 - Mergelstetten, started in April 2010	none	Consideration of cement specific issues are important in the selection of a potential vendor.
SCR current proposal for SCR in cement plants	Mannersdorf - dust loading 2000 mg; ESP + SCR; reduction 66%; 15 ppm ammonia slip; 360 deg C	none	Mannersdorf - high dust application requires 4 layers. \$5.3M Eu turnkey including SCR and ESP	none	
RELEVANT DATA REQUESTED BY VENDORS					
Data required by vendors (from Lafarge) to finalize SCR design	THC limit < 24 ppm or sum of 6 organics < 9 ppm	Fuel analyses, Ca content in dust, layout drawing	P2O5 in dust - 0.08% by mass in kiln feed; % Thallium in dust	Preheat curve	
SCR DESIGN AND OPERATING CONSIDERATIONS					
Design	downdraft	downdraft	downdraft	downdraft	
Recommended operating temperature range	350 deg C	350 deg C	350 deg C	350 deg C	570 - 660 deg F
Layout preference	Low dust configuration with 100 mg/Nm3 max	Assumed 50 mg/m3	High dust configuration, no ESP or Low dust configuration with ESP and high cleaning frequency	Assumed 50 mg/m3	SCR after existing ESP with expected dust load of 100 mg/Nm3
Catalyst design	Honeycomb design, 6m x 5m	Honeycomb, 150mm x 150mm x 1000mm	Honeycomb design; 12 modules, 4.9m x 4.6m cross section	Honeycomb	Honeycomb

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Appendix 2 – SCR Vendor Comparison (cont'd)

JOPPA KILN 1 SCR - VENDORS RECOMMENDATIONS					
DATE: Oct 25, 2010	GEA - Bischoff	Power Alstom	Cemcat (Elex/Polysius)	Babcock & Wicox	Recommendations for design considerations
No of layers recommended	2 + 1 spare	2 (NOx) + 2 (D/F) + 1 spare	3 + 1 spare	3 + 1 spare	4 maximum
Catalyst type	TiO ₂ base, V ₂ O ₅ catalyst		3% V ₂ O ₅	Va, Ti, W are active ingredients	TiO ₂ substrate, V ₂ O ₅ active
Pitch	6 mm	No less than 8 mm	8.2 mm	3.3 - 6 mm for low dust; 7 - 9 mm for high dust	Depend on selected vendor
Pressure drop	11 mbar across SCR	0.75" per layer; 5 - 6" total	6 mbar for SCR	1" per layer; add 2" for system	
Catalyst life	5 - 6 years	8,000 hrs - 16,000 hrs	7-25% activity loss in 7400 hrs.	16,000 hrs	8,000 - 16,000 hrs
Ammonia slip above baseline	10 ppm	2 - 5 ppm	15 mg/Nm ³	2 - 10 ppm	10 ppm
Recommended reagent	Aqueous ammonia, with twin fluid nozzles	Aqueous ammonia, with ammonia injection grid	Aqueous ammonia ahead of ESP	Anhydrous NH ₃ where permitting is easier; Aqueous NH ₃ is common;	Aqueous ammonia
Reagent rate	487 - 715 kg/h	130 kg/h	1200 kg/h		2.3 to 3.4 gpm
Reagent storage	25,000 gallons		200 m ³	18,000 gallons	
Reduction efficiency	80% on NO _x	80%	< 100 mg.Nm ³ of NO _x	80% on NO _x ; 10 ppm slip, 80% on D/F	80% on NO _x
SCR Bypass	Recommended for start-up and SCR malfunction	Recommended for start-up	Recommended for start-up	Recommended for start-up	Recommended
MAJOR UNRESOLVED ISSUES WITH SCR IN CEMENT PLANTS					
Catalyst cleaning - hard coating forms on top of the catalysts blocking air flow	Blower and nozzles with heater; one system per layer for cleaning the catalysts	2 Sonic Horns per layer; 8 total	2 ElexCemcat blowers per layer, 110 kW each, at >160 deg C	Soot blowers with electric air heater to 120 deg C; 2 per layer	Soot blowers with heaters
Catalyst deactivation caused by poisoning (foreign molecules bind with catalyst) and sintering with pores blocked and fused at high temperature	Arsenic, Phosphorus, HCL, Thallium and Antimony are not expected in the kiln gases!!	Extensive experience in power industry; none in cement; Alkalies (oxides of Na and K) acts as poison; deactivation also caused by blocking of pores	Thallium and alkali and chloride salts are present in the dust	Catalyst Outage Protection to prevent damage by moisture and poisoning	Impact of poisoning and deactivation on the NO _x emission reduction efficiency needs to be evaluated during optimization phase
INDICATIVE TIMELINE FOR IMPLEMENTATION FROM P.O					
SCR implementation schedule - from P.O to startup	18 months from P.O, including 1 month for training and commissioning	24 months including commissioning	15 months including commissioning.	24 months including 1 month for commissioning	18 - 24 months after P.O. after design report and permit approval

End of Report

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